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Chapter

Body Weight Gain and Carcass Yield Characteristics of Wollo Highland Sheep and Their F_1 Crossbreeds

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Abstract

In the study area, sheep flocks are managed under traditional extensive systems with no or minimal inputs and improved technologies, which results in low productivity. The available natural pasture lands are overloaded with livestock beyond optimum carrying capacity that has resulted in overgrazing and land degradation. This indicates the critical need of supplemental feed during feed-deficient period. The objective of the research was assessment of productive performance through on-station feedlot and natural pasture grazing effect on weight gain and carcass yield characteristics evaluation. The average daily weight gain (ADG), total body weight change and final body weights of supplemented groups significantly higher than ($p < 0.05$) non-supplemented groups. Hence, supplemented and non-supplemented Awassi crossbreds had higher daily weight gain and followed by supplemented Wollo highland group. Between genotypes, there is significant difference ($p < 0.05$) of rib-eye area, empty body weight, hot and cold carcass weight and cold carcass dressing percentage. Conversely, Wollo highland sheep has exhibited compensatory growth rate than others. Awassi crossbred lambs has higher weight gain and faster growth performance followed by Washera crossbred one. Therefore, local breed productive performance improvement practices have to continue and need adjustment of breeding strategies with a definite breeding plan.

Keywords: body weight, carcass, Awassi and Washera, F_1 crossbred and Wollo highland

1. Introduction

Ethiopia is not only rich in sheep population but also rich in sheep genetic diversity, which developed by natural selection and potential genetic resources of sheep breeds [1]. In the highlands of the country, about 75% of sheep population are found, while the remaining 25% are distributed in the lowlands [2]. Sheep production is a major component of the livestock sector in Ethiopia, owing to the large population of 30.70 million sheep are estimated to be found in the country, out of which about 72.14% are females, and about 27.86% are males [3]. The small ruminants account for 40% of cash income earned by farm households, 19% of the total value of subsistence food derived from all livestock production, and 25% of total domestic meat consumption [4]. Smallholder sheep production is the major source of food security serving a diverse function, including cash income, savings, fertilizer, socio-cultural functions and fiber production. Sheep are particularly important for farmers in the subalpine highlands and pastoralist/agropastoralist where crop production is unreliable. Moreover, despites its socio-cultural importance, sheep resources significantly contributed for foreign currency earning accounting for the live animal exports [1].

The cool highland sheep production systems in most highland areas are characterized by erratic and unevenly distributed rainfall, recurrent drought, and scarcity in livestock feeds and feed that is poor in quality [5]. In those production environments, the role of sheep in supporting the livelihood of smallholder farmers is increasing due to recurrent crop failure [5, 6]. However, the sheep flocks are managed under traditional extensive systems with no or minimal inputs and improved technologies, which results in low productivity. They depend on natural pasture and fibrous crop residues for their survival, growth and reproduction. The available natural pasture lands are overloaded with livestock beyond optimum carrying capacity that has resulted in overgrazing and land degradation [7, 8]. This indicated the critical need of supplemental feed during the feed-deficient period and wise management of communal and private natural pasture grazing. A limited supply of nutrients in the sheep's diet can lead to weight loss, low fertility, high mortality, increased risk of disease and poor wool growth. Sheep need a balanced diet containing energy (fat and carbohydrates), protein, vitamins, minerals, and water. Sheep and goat production in Ethiopia suffers feed shortages at all levels with an estimated 40% deficit in the national feed balance. This is aggravated by seasonal availability of forage and crop residues in the highlands and by recurrent and prolonged drought in the lowlands.

Therefore, the study was accomplished on, assessment of productive performance through on-station feedlot based and natural pasture grazing weight gain performance and carcass yield characteristics evaluation of indigenous Wollo highland sheep breed and their F_1 crossbreds with 75% Awassi and pure indigenous Washera breed rams.

The specific objectives of the study are:

- to evaluate on-station feedlot weight gain and carcass yield characteristics of Wollo highland sheep and their F_1 crossbreds of Awassi and Washera sheep breeds.
- to assess natural grass grazing value as basal diet for the study breeds supplemented by concentrated feed.

2. Material and methods

2.1 Description of the study area

This research was conducted from 2018 to 2019 in the two selected areas of Dessie Zuria and Kutaber districts in South Wollo Zone of Amhara Region, Ethiopia. The geographical location of South Wollo Zone is delimited with North Shewa and Oromia region in the Southern part, East Gojjam in the West, South Gondar in the Northwest, North Wollo in the North, Afar Region in the Northeast and Argobba district of the Oromia Zone in the Eastern part (**Figure 1**).

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Figure 1.
Description of the study area.

2.2 Experimental design and treatments

A 3 × 2 factorial experimental design arrangement of three genotype and two feeding type factors with six treatment levels (three genotypes by two feeding type's combinations) and six replications were used. The three genotypes belonging to 50% Awassi F_1 crosses, 50% Washera F_1 crosses and 100% local Wollo highland lambs were grouped in to three by their genotypes and in to two by their feeding types of supplemented and non-supplemented groups for each genotypes. The supplemented and non-supplemented feeding types randomly assigned for each 36 experimental animals.

Both supplemented and non-supplemented groups grazed for 8 hours/day as a basal diet with rotational grazing system and animal holding of 36 sheep/0.5 ha paddock/day. The supplemented group fed at the rate of 1% of their body

Local name	Scientific name	Growth form
Akirma	*Cynodon nlemfuensis*	Grass—perennial
Tult	*Asarum canadense*	Herb—annual
Sindedo	*Urochloa brizantha*	Grass—perennial
Serdo	*Cynodon dactylon*	Grass—annual
Gicha	*Cyperus rotundus*	Grass—annual
Gazia	*Dactylis glomerata* L.	Grass—perennial
Arintata	*Trifolium repens*	Herb—annual
Others	—	—
Muja	Snowdenia polystachya	Grass—annual
Gudign	*Dichondra repens*	Herb—annual
Ketema	*Cyperus polystachyos*	Grass—perennial
Bare land	—	—

Table 1.
Species composition of private owned natural pasture grass land.

weight/day of concentrate mix diet, whereas the non-supplemented group fed only natural pasture grazing area for 8 hours/day from 8:00 AM to 5:30 PM with a 1 hour rest from 12:30 AM to 1:30 PM and had free access of drinking water.

2.3 Experimental animals grazing management

The grazing land characterized by both annual and perennial grass such as *Cyperus rotundus*, *Dactylis glomerata Cynodon nlemfuensis*, *Cynodon dactylon*, *Cyperus polystachyos* and *Urochloa brizantha* (**Table 1**). The size of natural pasture grazing area was 2.5 ha of land and that sub-divided into five paddocks with each individual paddock size was 0.5 ha.

2.4 Body weight gain and linear body measurements

Lambs were weighed at 15 days of interval for 1 year in the last week of each month using a 0.1 kg precision scale. Lambs were weighed at birth and fortnightly thereafter up to weaning. After weaning at the age of about 90 days they were weighed in 15 days interval together with the rest of the flock. Lamb body weights were adjusted by age.

The average daily weight gain (ADG) was calculated using the following formula at on-farm growth performance study:

$$ADG = \frac{dW2\,Kg + W1Kg}{A} * 1000 \tag{1}$$

where ADG g = average daily gain in gram, W1 kg = birth weight or weight at the preceding age, W2 kg = weight at a given age, and A = age in days or days between weighing dates.

Average daily gain was calculated for the following stages of growth:
(a) pre-weaning weight average daily gain (PreADG) ADG = birth to 90 days of age, (b) post-weaning weight average daily gain (PoADG) = birth to 365 days of age, and (c) weaning weight = at average body weight at 90 days.

Average daily weight gain of ram lambs in the on-station growth performance evaluation was also calculated using the following formula:

$$ADG = \frac{FWT\,Kg + IWTKg}{AD} * 100 \tag{2}$$

where FWT = final body weight, IWT = initial body weight, and D = number of fattening days.

Linear body measurements were taken together with 3 months of interval measurements (from 3 months of age to 12 months). All body measurements were taken with a measuring tape in centimeter and measured to the nearest 0.5 cm. Linear body measurements traits were taken: (a) heart girth is the circumference of the chest posterior to the forelegs at right angles to the body axis, (b) wither height is the highest point measured as the vertical distance from the top of the shoulder to the ground, (c) body length is the distance between the crown and the sacrococcygeal joint, (d) tail width is directly behind the tuber ichiad, and (e) tail circumference is directly behind the tuber ichiad.

Model 1. On-station growth of initial and final body weight, average daily gain (ADG) of ram lambs (9 months–365 days of age):

$$\mathrm{Yijklm} = \mu + \mathrm{Bi} + \mathrm{F}_l + (\mathrm{B}_i \times \mathrm{F}_l)\mathrm{ijm} + \mathrm{eijklm} \tag{3}$$

where Yijklm = average daily gain (ADG) and body weight change, μ = overall mean, Bi = fixed effect of the *i*th breed (i = Awassi F_1 crossbred, Washera F_1 crossbred and local Wollo highland breed), F_l = fixed effect of the feeding type (1 = supplemented, 2 = non-supplemented), $(B_i \times F_l)_{il}$ = breed by feeding type interaction effect and eil = effect of the nth random error.

Model 2. Weight and linear body measurements of male lambs (90–365 days of age):

$$\mathrm{Yij} = \mu + \mathrm{Bi} + \mathrm{Btj} + \mathrm{eij} \tag{4}$$

where Yij = body weight and linear body measurements at 90, 180, 270 and 365 days of age, μ = overall mean, Bi = fixed effect of the ith breed (i = Awassi F_1 crossbred, Washera F_1 crossbred and local Wollo highland breed), Btj = fixed effect of the jth birth type (j = single, twins), eij = effect of the oth random error.

Model 3. Body weight gain, carcass and non-carcass parameters:

$$\mathrm{Yijk} = \mu + \mathrm{Bi} + \mathrm{Fj} + \mathrm{Wk} + \mathrm{eijk}, \tag{5}$$

where Yijk = body weight gain, carcass and non-carcass parameter, μ = mean, Bi = effect of the ith breed (i = Awassi F_1 crossbred, Washera F_1 crossbred and local Wollo highland breed), Fj = the fixed effect of feeding type (j = supplemented, non-supplemented), Wk = the random effect of body weight (k = birth weight, pre-weaning weight ADG, weaning weight, post-weaning weight ADG and yearling weight, empty body weight, pre-slaughter weight), eijk = effect of the kth random error.

2.5 Data analysis

According to a 3 × 2 factorial statistical designs of the breed and diet as main effects and the PROC GLM of multivariate analysis package of the SAS Windows 9.0-2004 system used for those data fitted with the main factors of breed, feeding type, sex, birth type and parity effects on body weight gain response variable in the model. Initial body weight was also used as a covariate factor in the model to control the residual effects of initial body weight on consecutive rate of body weight gain. The dependent variables include body weight, average daily weight gain, survival rates, linear body measurements, reproductive traits and carcass yield characteristic parameters were considered in the GLM multivariate analysis of variance. The stepwise procedure of Pearson correlation of the SAS system was used to see the effects of association between body weight and linear body measurement traits. Tukey's standardized range significance test was used to compare the different groups of mean.

3. Results

3.1 Effects of genotype and supplementation feed on ram lambs growth rate

Genotype and supplementation diet effect on ram lambs' average body weight and their daily weight gain is presented in **Table 2**. Initial body weight had significant ($p < 0.05$) difference between genotypes and used in the covariate analysis model to avoid its residual effect on consecutive body weight gain and to quantify the genotype effect. However, it has non-significant difference within genotypes. The between and within genotype variations were continued throughout 10, 20 and

	Awassi genotype		Wollo genotype		Washera genotype		
ABW (kg)	T1	T2	T1	T2	T1	T2	Sig.L
IBW	31.6 ± 1.0^{a}	31.5 ± 0.8^{a}	21.9 ± 0.7^{b}	21.4 ± 0.5^{b}	26.4 ± 0.7^{c}	26.6 ± 0.7^{c}	***
10 days	33.4 ± 0.9^{a}	34.0 ± 0.9^{a}	26.9 ± 0.9^{b}	24.5 ± 0.9^{b}	29.0 ± 0.5^{c}	27.5 ± 0.5^{d}	*
20 days	33.3 ± 1.1^{a}	34.1 ± 1.1^{a}	26.6 ± 1.1^{c}	24.2 ± 1.1^{b}	28.8 ± 0.6^{c}	26.9 ± 0.6^{c}	*
30 days	36.7 ± 1.3^{a}	36.9 ± 1.3^{a}	28.4 ± 1.3^{b,c}	26.3 ± 1.3^{b}	30.3 ± 0.7^{c}	29.0 ± 0.7^{c}	*
40 days	37.8 ± 1.3^{a}	37.7 ± 1.3^{a}	29.3 ± 1.3^{b}	27.0 ± 1.3^{d}	30.6 ± 0.7^{c}	29.2 ± 0.7^{c}	*
50 days	38.3 ± 1.7^{a}	36.1 ± 1.7^{b}	30.8 ± 1.7^{c,e}	28.4 ± 1.7^{d}	31.1 ± 0.9^{e}	29.4 ± 0.9^{c,d}	*
60 days	38.8 ± 1.8^{a}	35.8 ± 1.8^{b}	32.4 ± 1.7^{c}	29.8 ± 1.8^{d}	32.1 ± 1.0^{c}	29.9 ± 1.0^{d}	**
70 days	39.9 ± 1.8^{a}	37.3 ± 1.8^{b}	33.3 ± 1.8^{d}	30.4 ± 1.8^{c}	32.2 ± 1.0^{c,d}	30.6 ± 1.0^{e,c}	**
80 days	41.4 ± 1.8^{a}	38.2 ± 1.8^{b}	34.4 ± 1.8^{c}	31.1 ± 1.8^{d}	33.1 ± 1.0^{c}	31.3 ± 1.0^{d}	**
FBW	45.5 ± 1.4^{a}	42.4 ± 1.4^{b}	35.2 ± 1.3^{c}	31.6 ± 1.4^{d}	34.4 ± 0.7^{c}	32.4 ± 0.7^{d}	***
BWC	16.1 ± 1.1^{a}	13.4 ± 1.1^{b}	8.9 ± 1.1^{c}	7.5 ± 1.1^{d}	6.0 ± 0.6^{e}	5.9 ± 0.6^{e}	**
ADG (g)	178.5 ± 12.3^{a}	148.3 ± 12.4^{b}	98.4 ± 12.2^{c}	83.5 ± 12.3^{d}	66.6 ± 6.7^{e}	65.2 ± 6.7^{e}	**

$^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.
ABW, average body weight gain; FBW, final body weight gain; BWC, body weight change; ADG, average daily weight gain; T1, supplemented; T2, not-supplemented; superscript with the same letter is not significant and different letters has significant difference (across the row); SE, standard error of the mean.

Table 2.
Genotype and supplemented diet effect on ram lambs body weight gain.

30 days experimental period except supplemented Washera F_1 crossbreds and Wollo highland breed lambs and which were significantly higher than their non-supplemented group at 10 and 20 days treatment period, respectively. Despite the fact that at 30, 40, 50 and 60 days of feed treatment period the supplemented group of Wollo highland breed lambs had non-significant differences with both supplemented and non-supplemented Washera crossbred lambs and between breed variation eliminated. At 40 and 50 days, treatment period, except Wollo highland lambs the other genotypes have insignificant differences between supplemented and non-supplemented groups. Conversely, at 60 days of treatment period supplemented Wollo highland breed lambs had non-significant variation with both supplemented and non-supplemented Washera F_1 crossbred lambs and vice versa. Awassi F_1 crossbred lambs significantly ($p < 0.05$) higher average weight gain than both Wollo highland and Washera F_1 cross ram lambs throughout the experimental period (**Table 2**).

The total body weight changes from initial to final body weight higher in supplemented Awassi crossbred lambs and followed by their non-supplemented group. Supplemented and non-supplemented Wollo highland lambs observed better growth performance than Washera F_1 crossbreds. Therefore, on-station feed supplementation effect had fastest growth performance record with Awassi F_1 crossbred lambs than Wollo highland and Washera F_1 crossbred lambs. Supplemented Wollo highland lambs had faster growth rates than their non-supplemented group. Supplemented Washera crossbred lambs had a comparable body weight change to non-supplemented group.

Even though, Wollo highland breed had faster body weight change and average daily gain than Washera F_1 crossbred lambs, the supplemented group of Washera crossbred lambs had higher final body weight gain than supplemented Wollo highland breed lambs. The final body weight of non-supplemented Washera crossbred lambs had higher than non-supplemented Wollo highland lambs.

3.2 Genotypes and supplementation effect on carcass characteristic performance

Carcass and non-carcass yield characteristics included, pre-slaughtered weight, slaughter body weight, empty body weight, fasting loss, hot carcass weight, cold carcass weight, total edible proportion, non-carcass organs, rib-eye area, fat and lean meat thickness and commercial yield were presented in **Table 2**.

Slaughtered and empty body weight bases of the supplemented and non-supplemented groups did not significant difference for each genotype. However, significant variations recorded between the three genotypes. Subsequent to 24 hours of fasting period (except water) the body weight losses and hot carcass weight had comparable value within breeds. However, Awassi crossbred lambs lost more than Washera crossbred and Wollo highland breed lambs. Even though Awassi F_1 crossbred lambs lost higher body weight than others during fasting period, it is significantly ($P < 0.05$) higher hot carcass weight than Washera F_1 crossbreds and Wollo highland ram lambs. Nevertheless, fasting loss and hot carcass weight have comparable value between supplemented and non-supplemented Wollo highland and Washera crossbred lambs.

Fat thickness of both supplemented and non-supplemented groups of Awassi crossbred lambs had significantly higher than Wollo highland and non-supplemented Washera crossbred lambs. Despite the fact that, supplemented Washera crossbred lambs, had comparable fat thickness with supplemented Awassi crossbred lambs. Awassi crosses had significantly higher a total non-carcass weight than both Washera and Wollo highland breed lambs, but did not show within breed difference. Between supplemented and non-supplemented Washera genotype and supplemented local Wollo highland breed did not have significant variation of total non-carcass components and non-supplemented Wollo highland lambs significantly lower than others.

3.3 Carcass yield traits correlation coefficient analysis

Slaughtered body weight had strong positive and significant correlation with empty body weight, hot and cold carcass weight, rib-eye area (cm^2), fat thickness (mm^2) and slight positive correlation with lean thickness (mm^2). However, it had inverse correlation with commercial yield % (cold carcass weight/slaughtered body weight $\times$ 100) carcass trait. Empty body weight has strong and positive correlation with cold and hot carcass weight, and rib-eye area (cm^2). However, poor and positively associated with lean meat thickness (mm^2).

Hot carcass weight had perfect positive significant correlation with rib-eye area (cm^2) of lean meat composition, medium positive correlation with fat thickness and poorly correlated with amount of commercial yield (**Table 3**). The cold carcass weight trait has positive and intermediate correlation with rib-eye area and with lean meat thickness and poorly positive correlation with commercial yield feature. Likewise, rib-eye area carcass trait contents had medium positive association with fat thickness and lean meat thickness attribute. However, it had poor and positive correlation with commercial yield percentage composition, while fat thickness amount of the carcass had positive and medium correlation with lean meat thickness in the entire carcass, but negatively correlated with commercial yield percentage

Carcass traits	Awassi F_1 crossbreds		Wollo highland breed		Washera F_1 crossbreds		
	T1	T2	T1	T2	T1	T2	Sig. L
SBW (kg)	47.4 ± 0.8^a	44.6 ± 0.6^b	32.5 ± 1.4^c	29.3 ± 1.1^d	32.6 ± 0.5^c	32.2 ± 0.5^c	***
EBW(kg)	35.3 ± 1.3^a	32.4 ± 1.3^a	24.5 ± 1.7^b	20.5 ± 1.7^b	26.9 ± 0.9^c	26.8 ± 0.9^c	**
HCW (kg)	20.8 ± 1.6^a	20.2 ± 1.6^a	14.7 ± 1.2^b	13.5 ± 1.2^b	16.0 ± 0.5^c	13.2 ± 0.5^b	***
CCW (kg)	18.3 ± 1.4^a	18.2 ± 1.4^a	11.7 ± 1.0^b	11.6 ± 1.0^b	14.9 ± 0.4^c	$12.5 \pm 0.4^{c,b}$	**
HCWDP (%)	43.9 ± 3.2^a	45.3 ± 3.2^b	45.2 ± 3.2^b	46.1 ± 3.2^b	49.1 ± 0.3^c	41.0 ± 0.3^d	*
CCWDP (%)	38.6 ± 2.9^a	40.8 ± 2.9^b	36 ± 5.2^c	$39.6 \pm 5.2^{a,b}$	45.7 ± 1.8^d	38.8 ± 1.8^a	*
TEP (kg)	25.1 ± 1.8^a	23.8 ± 1.8^a	17.4 ± 1.6^b	17.2 ± 1.6^b	19.6 ± 0.7^c	17.6 ± 0.7^b	**
REA (cm^2)	15.9 ± 0.2^a	15.5 ± 0.2^a	7.3 ± 0.1^b	6.5 ± 0.1^b	9.2 ± 0.1^c	7.3 ± 0.1^b	**
TNCW (kg)	14.5 ± 1.3^a	$12.2 \pm 1.3^{a,b}$	10.8 ± 1.3^b	6.9 ± 1.3^c	10 ± 1.3^b	12.9 ± 1.3^b	*
FT (mm)	0.3 ± 0.1^a	0.3 ± 0.1^a	0.2 ± 0.0^b	0.2 ± 0.0^b	0.3 ± 0.2^a	0.2 ± 0.2^b	*

T1, supplemented; T2, non-supplemented; SBW, sloughter body weight; EBW, empty body weight; HCW, hot carcass weight; CCW, cold carcass weight; HCWDP, hot carcass weight dressing percentage; CCWDP, cold carcass weight dressing percentage; TEP, total edible propertion; REA, rib-eye area; TNCW, total non-carcass weight. Superscript with the same letter is not significant and different letters has significant difference.

Table 3.
Analysis of variability for genotype and diet effects on carcass traits.

composition. In other ways lean meat content of the carcass had poor positive correlation with commercial yield of the whole carcass composition (**Table 3**).

3.4 Genotype and supplementation effects on carcass morphometric traits

Carcass morphometric characteristics of the present study were described by carcass length, lean meat weight, lean meat length, compactness index, chest width, shoulder width, and lean meat thickness presented in **Table 4**. Hence, the length of the carcass and lean meat had significantly higher for Awassi and followed by Washera crossbred lambs. Between the supplemented and non-supplemented groups of each genotypes, comparable carcass and lean meat length were recorded, however, significantly different between genotypes. Lean meat thickness significantly higher for both supplemented and non-supplemented Awassi F_1 crossbred

Body weight (kg)	SBW	EBW	HCW	CCW	REA	LMT
EBW	0.87^{**}					
HCW	0.82^{**}	0.77^{**}				
CCW	0.86^{**}	0.79^{**}	0.98^{***}			
REA (cm^2)	0.82^{**}	0.77^{**}	0.99^{***}	0.98^{***}		
LMT (mm^2)	0.52^{*}	0.50^{*}	0.54^{*}	0.554^{*}	0.54^{*}	
CY (%)	−0.15	−0.01	0.42	0.36	0.42	0.08

SBW, slaughter body weight; EBW, empty body weight; HCW, hot carcass weight; CCW, cold carcass weight; REA, rib-eye area; LMT, lean meat thickness; CY, commercial yield.
***Correlation is significant at the 0.001 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).
*Correlation is significant at the 0.05 level (two-tailed).

Table 4.
Pearson correlation coefficient of carcass yield characterestics.

lambs. Between supplemented and non-supplemented groups of Wollo highland breed and Washera, crossbred lambs had significant difference.

The carcass composition of lean meat weight amount is significantly higher with Awassi crossbred lambs than Washera crossbred and Wollo highland breed lambs. Supplemented Wollo highland lambs and Washera crossbred lambs had proportional amount of lean meat weight. The carcass compactness index is measured by grams of lean meat per centimeters of its length. Carcass compactness index, chest and shoulder width had comparable records for all genotypes except chest width for Awassi genotype.

3.5 Genotype and supplementation feed effects on non-carcass fat distribution

The effects of genotype and supplementation diet effect on non-carcass fat distribution presented in **Table 5**. Thus, the non-carcass fat contents around the scrotal fat organ had not significant variation between supplemented and non supplemented group of each genotypes. However, between Wollo highland breed and Awassi crossbred lambs had a significant variation of scrotal fat contents. Likewise, Washera and Awassi crossbred lambs had significant differences between supplemented and non supplemented groups of scrotal fat contents. While, kidney fat composition of Awassi crossbred lambs and Wollo highland breed lambs had significantly lower than that of Washera crossbred lambs (**Table 5**).

Whereas, significant difference recorded between three genotypes of total non carcass fat contents. Both supplemented and non supplemented group of Awassi F1 crossbred lambs had higher composition of total non-carcass fat contents followed by Washera crossbred lambs. In general all supplemented groups were comprised of higher numerical value of non carcass fat composition, but not significantly different with non supplemented groups.

3.6 Genotype and feed effects on non-carcass edible and non-edible components

According to intellectual prohibited cultural and religious taboo of the local communities the edible components of non-carcass organs were presented as liver, tongue, heart, kidney, empty gastrointestinal part and tail fat were the most

Carcass morphometric traits	Awassi F_1 crossbreds		Wollo highland breed		Washera F_1 crossbreds	
	T1	T2	T1	T2	T1	T2
Carcass length (cm)	74.3 ± 1.2^a	73.7 ± 1.2^a	63.0 ± 1.9^b	64.0 ± 1.9^b	70.3 ± 2.2^c	68.0 ± 2.2^c
Lean meat thickness (mm)	12.5 ± 2.4^a	11.0 ± 2.4^a	9.0 ± 0.7^b	6.4 ± 0.7^c	12.0 ± 0.5^a	6.3 ± 0.5^c
Lean meat weight (kg)	0.7 ± 0.03^a	0.7 ± 0.03^a	0.5 ± 0.1^b	0.5 ± 0.1^b	0.6 ± 0.1^b	0.5 ± 0.1^b
Lean meat length (cm)	55.3 ± 1.2^a	54.7 ± 1.2^a	44.0 ± 1.9^b	45.0 ± 1.9^b	51.3 ± 2.2^c	$49. \pm 2.2^c$
Compactness index (g/cm)	12.1 ± 0.8	12.0 ± 0.8	11.8 ± 0.8	11.9 ± 0.8	12.4 ± 0.9	10.5 ± 0.9
Chest width (cm)	13.9 ± 0.6^a	13.7 ± 0.6^a	9.2 ± 1.0^b	8.1 ± 1.0^b	10.9 ± 0.9^b	8.8 ± 0.9^b
Shoulder width (cm)	17.7 ± 0.6	18.1 ± 0.6	14.4 ± 0.6	14.2 ± 0.6	17.1 ± 0.6	15.0 ± 0.6

T1, supplemented; T2, non-supplemented; cm, centimeters, kg, kilograms, mm, millimeters, g, gram. Superscript with the same letter is not significant and different letters has significant difference.

Table 5.
Between and within genotype carcass morphometric traits variability.

Non-carcass fat traits (g)	Wollo highland breed		Awassi F_1 crossbreds		Washera F_1 crossbreds	
	T1	T2	T1	T2	T1	T2
Scrotal fat	8.7 ± 2.9^c	10.7 ± 2.1^c	33 ± 6.7^b	40 ± 6.7^b	13.7 ± 4.4^c	15.7 ± 4.4^c
Pelvic fat	29.3 ± 3.5^a	26.7 ± 3.5^a	30.7 ± 3.1^a	27.7 ± 3.1^a	47.0 ± 10.6^c	38.3 ± 10.6^c
Kidney fat	25.3 ± 2.0^a	23.3 ± 2.0^a	60 ± 18^a	63 ± 18.0^a	171.0 ± 52.4^c	89.3 ± 52.4^c
Mesentery fat	55.3 ± 8.5^a	43.3 ± 8.5^a	414 ± 38.7^b	317.7 ± 38.7^b	233.3 ± 64.1^c	145.0 ± 64.1^c
Overall	117.7 ± 12.6^a	103.6 ± 12.6^a	537.7 ± 54.7^c	448.4 ± 54.7^d	465 ± 129.7^c	288.3 ± 129.7^b

T1, supplemented; T2, non-supplemented; g, grams. Superscript with the same letter is not significant and different letters has significant difference.

Table 6.
Non-carcass fat distribution traits variability between and within genotypes.

common. Hence, liver and heart weight had comparable value for Wollo highland and Washera crossbred lambs; however, Awassi crossbred had significantly higher amount of liver and heart weight. At the same time, non-significant record was observed between supplemented and non-supplemented groups of all genotypes. While the kidney and empty gastrointestinal weight had comparable value for all genotypes and feeding type factors, there was no significant difference both within and between genotypes and feeding types. Whereas the tail weight had comparable value between the three genotypes, Washera crossbred had a numerically higher quantity of tail weight than others (**Table 6**).

Except kidney weight of non-supplemented Awassi and Washera F_1 crossbreds and supplemented Wollo highland breed lambs, the edible non-carcass components not significant variation between supplemented and non-supplemented groups. However, except kidney weight and GIT empty weight, genotype had significant variation on non-carcass edible components. Except tail fat weight composition, in all edible non-carcass components of the Awassi crossbred lambs had the largest portion (**Table 6**).

Wollo highland breed had a comparable tail fat composition with Awassi crossbred lambs. However, both genotype and supplementation diet did not had significant differences with kidney and empty gastrointestinal weight of supplemented and non-supplemented groups. Subsequently, the non-edible, non-carcass components were skin, head, testicle and genital organ, blood, bladder, pancreas, feet, digestive contents and spleen which prohibited by the local communities cultural and religious taboo.

4. Discussion

4.1 Genotype and supplemented diet effects on body weight gain and carcass traits

The availability and supply of animal feed in the tropics is not constant in terms of both quantity and quality particularly in arid and semiarid regions seasonal fluctuation in the growth rate of animal in these regions [9, 10]. This is particularly true in the study area, where the main source of animal feed is grazing on natural pasture. For this reason, to use whatever available resource more economically, it will be advantageous to identify those breeds of animals which are more efficient meat producers [11] or animals which have high performance in feed conversion efficiency to produce saleable products [11].

4.2 Effects of genotype and supplementation on body weight gain performance

Genotypes and supplementation feed effects on ram lambs' body weight gain presented in **Table 2**. Initially the body weight gain of the three genotypes significantly different ($p < 0.05$) each other and the differences were come from breed effects but not significant differences within group in each treatment. To avoid the effects of initial body weight on the successive body weight gain, covariate analysis was used and the adjusted initial body weight at 26.56 kg of all genotypes. In the present study, significantly higher average daily weight gain observed on the supplemented group implied that they were adequately fed and their maintenance and growth nutrient requirements were satisfied compared with non-supplemented groups (grazing only).

The average daily weight gain (ADG), the rate of body weight change and final body weights of supplemented group of Awassi, and Washera F_1 crossbred and Wollo highland breed ram lambs were significantly higher ($p < 0.05$) than non-supplemented groups. As a result, Awassi F_1 crossbred lambs' growth rate had significantly greater ($p < 0.05$) than both Wollo highland and Washera F_1 crossbred ram lambs throughout the experimental period and followed by supplementing Wollo highland breed ram lambs. The reason behind this might be the genetic potential difference of the three genotypes affecting average daily weight gain efficiency with different extent. Therefore, genotype is the limiting factor affecting average daily weight gain of lambs and in agreement with reported by Hammell and Laforest [12] for Polled Dorset, Hampshire and Romanov breeds.

The total amount of body weight change and the rate of daily weight gain indicated Wollo highland breed lambs were significantly greater than both supplemented and non-supplemented groups of Washera F_1 crossbred lambs. This indicated improved grazing management condition and supplementation diet of Wollo highland breed lambs can have comparable body weight gain potential with their Washera F_1 crossbreds with the same management condition [13–15].

In general the Awassi F_1 crossbred ram lambs have a promising growth performance with supplementation of local available concentrate feed. Hence, with controlled management condition of natural pasture grazing has contributed to better growth performance of ram lambs body weight gain. Furthermore, Washera F1 crossbreed lambs have an imperative body weight change and can be another alternative to enhance genetic potential of pure local Wollo highland breed, and in addition to this, inbreeding coefficient risk can be reduced. Moreover, cost-effective concentrate feed supplementation on natural pasture grazing need appropriate attention by fatteners, and other sheep producers. Together with this private controlled grazing management, system had also played a great role to improve the body weight gain of ram lambs through quality pasture production.

4.3 Effects of genotype and supplemented feed on carcass yield characteristics

Carcass composition used as tool to characterize breeds for possible identification of potential genetic resource for lean lamb production and also to identify management alternatives to suit different breeds [16]. Therefore, breed is known to influence not only carcass composition and quality but also carcass conformation as well, differences in carcass merits between breeds is likely to govern the choice and development of breeds for specific production objectives.

Slaughter and empty body weight between supplemented and non-supplemented groups variation not significant for all genotypes. The reason behind this might be less significant variation between supplemented and non-supplemented body weight before slaughter and relatively comparable amount of fasting loss. Nevertheless, significant variations between the three genotypes recorded, and which in agreement with Orr [17] and Lakew et al. [18]. Subsequent to 24 hours of fasting period, the body weight losses had a comparable amount for all genotypes and not significant variation observed. The loss of rumen contents through defecation and urination effects of fasting period not significantly different among genotypes (**Table 7**).

Hot carcass weight has comparable value between supplemented and non-supplemented groups. However, between genotypes a significant variation ($p < 0.001$) reported and which in agreement with Orr [17] and Lakew et al. [18]. Therefore, Awassi F_1 crossbred ram lambs significantly higher ($p < 0.001$) hot carcass weight than Wollo highland and Washera F_1 crosses (**Table 2**). This is because of higher slaughtered body weight and higher average daily weight gain (ADG) effect and their comparable fasting loss. Assefu [19, 20] reported there was no breed effect in hot carcass weight between Horro and Washera breeds and which disagree with present study.

Cold carcass weight used as commercial carcass yield indicator trait used for productive performance tools to evaluate the productivity of a given meat animals. Awassi crossbred lambs' cold carcass weight significantly ($p < 0.05$) greater than both Washera crosses and Wollo highland breed lambs. Within each genotype, cold carcass weight did not have significant difference because of the higher amount of chilling loss rate of supplemented groups (**Table 7**). This indicated that, the supplemented feed does not bring significant impact on cold carcass weight and agreement with Awgichew [10] for Menz and Horro breed lambs and Jorge et al.

Non-carcass components	Awassi crosses (means)		Wollo highland breed (means)		Washera crosses (means)			
	T1	T2	T1	T2	T1	T2	SE	P-value
I. Edible non-carcass traits								
Liver (g)	717.0^a	541.3^a	332.0^b	384.3^b	445.0^c	453.0^c	76.0	**
Tongue (g)	137.8^a	143.2^a	109.3^b	114.3^b	91.9^c	89.8^c	7.0	***
Heart (g)	190.3^a	127.3^a	61.3^c	68.3^c	68.3^c	75.3^c	25.5	**
Kidney (g)	63.3^a	66.0^b	64.3^{a,b}	59.0^c	54.0^c	66.0^b	31.4	*
GIT empty (g)	1900.0	1633.3	1611.3	2215.0	1779.3	1633.3	330	ns
Tail fat (g)	987.3	951.0	1106.7	920.0	1151.3	1213.3	100.9	ns
II. Non-edible non-carcass traits								
Skin (g)	3600.0^a	3766.7^a	3700.0^a	3133.3^b	5100.0^c	5033.3^c	255.0	**
Head (g)	1773.3^a	1733.3^a	2110.0^b	2206.7^b	2660.0^c	2763.3^c	134.9	**
Testicle (g)	420.0^a	420.0^a	310.0^b	310.0^b	540.0^a	430.0^a	56.0	***
Blood (g)	1336.7^a	1300.0^a	873.3^b	937.3^b	2033.3^c	1823.3^c	181.3	**
Bladder (g)	67.3^a	68.7^a	57.3^b	63.3^b	72.3.0^a	64.0^a	2.3	**
Feet (g)	247.7^a	249.7^a	214.0^a	194.7^b	203.7^b	217.7^a	16.4	*
Digestive content (g)	8400.0^c	8300^c	4222.0^a	5551.7^b	3466.7^a	4337.3^a	725.2	**
Spleen (g)	41.7	44.0	32.7	45.0	33.7	30.3	4.7	ns

T1, supplemented; T2, non-supplemented; ns, non-significant; GIT, gastrointestinal track and SE, standard error of the mean. Superscript with the same letter is not significant and different letters has significant difference.

Table 7.
Genotype and diet effects on edible and non-edible non-carcass components.

[21] for Chilote and Suffolk breeds in Chile Island. The chilling loss of cold carcass weight may vary between 1 and 7%, usually found close to 2.5% [22]. Moreover, sex, weight, fat covering of the carcass, temperature, and humidity in the cold storage chamber and the handling of the carcasses [23, 24] influence cold carcass characteristic.

Dressing percentage is described as the proportion of carcass weight to slaughtered body weight and it helps to assess meat productivity of the animals. Nutrition influences dressing percentage through variation in weight of mesentery contents and variation in actual organ weights [25, 26]. In agreement with the present finding, Awgichew [10] reported, regardless of the clear tendency of Horro lambs having a heavier hot and cold carcass weight, but did not differ significantly from Menz breed in dressing % and the loss of carcass moisture (shrinking %) after an overnight cooling. The present finding reported, hot carcass weight dressing percentage (HCCWDP) does not have significant difference both between and within genotype and which in agreement with Awgichew [10] and Jorge et al. [21]. Concurring with this report, an experimental trial conducted by Mazemder et al. [27] on grazing local sheep supplemented and with non-supplemented of 100, 200 and 300 g of concentrate feed/day; dressing percentage was similar among the treatments.

Rib-eye muscle area is mostly used as a tool to indicate the proportion of carcass muscling [28, 29]. In the present study the supplementation diet did not have a significant impact on rib-eye muscle area but numerical difference was observed. In line with the current finding, Gizaw [1] reported supplementation did not have significant effect on rib-eye muscle area in Somali goats fed hay and supplemented with different levels of peanut cake and wheat bran mixture. However, unlike this finding, Matiwas et al. [28] and Alemu [32] reported supplementation diet had a significant and positive effect on rib-eye muscle area. In concurrence with this finding, Matiwas et al. [31], Alemu [32]; Simret and Gizaw [30] reported rib-eye area had a significant variation between breeds. However, did not significant variation between supplemented and non-supplemented groups of Awassi crosses and Wollo highland breed lambs (**Table 7**). Nevertheless, supplemented and non-supplemented groups of Washera crossbreds had significant differences of rib-eye area composition. This fact is an indicator of better muscle development of supplementing Washera crosses than non-supplemented one. Hence, this rib-eye area muscle development is one of the merits to select Washera F_1 crossbred lambs for meat production objective. Both supplemented and non-supplemented Wollo highland and non-supplemented Washera crossbred lambs have relatively comparable rib-eye area muscle development (**Table 7**).

Except dressing percentage, almost all carcass characteristic extent both supplemented and non-supplemented Awassi crossbred had significantly higher than Wollo highland and Washera F_1 crossbred lambs. Hence, crossbreeding effect on genetic improvement practices using Awassi exotic breed had significant response associated with growth and carcass yield characteristic traits. As a result Awassi F_1 crossbred lambs had potential effect on meat production improvement objective and advisable to be selected for further breed productivity improvement program.

4.4 Genotype and supplemented feed effects on non-carcass fat distribution

The effects of genotype and supplementation diet on non-carcass fat distribution was presented in **Table 6**. Thus, non-carcass fat contents around the scrotal organ had not significant variation between supplemented and non-supplemented groups of the three genotypes. However, between Wollo highland breed lambs and Awassi F_1 crossbred lambs, significant variation of fat around scrotal organ observed.

Likewise, between supplemented and non-supplemented groups of Washera and Awassi F_1 crossbred lambs have significant difference fat around scrotal organ recorded. Subcutaneous fat content between Wollo highland and Awassi crossbred lambs had comparable value. However, Awassi crossbred and Wollo highland breed lambs significantly lower subcutaneous fat content than Washera crossbred lambs. The reason behind this, on fat deposition efficiency of Washera F_1 crosses genotype effect has more noticeable than Awassi crosses and Wollo highland breed.

The current study showed mesentery fat, kidney fat and subcutaneous fat decreased in non-supplemented ram lambs fed on natural pasture forage diet only. The current result is in agreement with reported by Karim et al. [33] and Papi et al. [34] on the concept of lambs with high forage quality tended to deposit less subcutaneous and intestinal fat contents. Lambs fed a concentrate diet displayed considerably greater fat accumulation than lambs raised on forage based diets [35]. The reduced non-carcass fat attributed to lower energy intake from forage [33]. In addition, high starch consumption the supplemented concentrate diets produces higher amounts of propionate, which ultimately increases insulin secretion and stimulates fat synthesis [35]. In agreement with this finding, Ibrahim et al. [29], Salo et al. [36], Roberto et al. [37] and Abebe and Tamir [38] reported the total fat contents of non-carcass components were significantly affected by the type of diet used. However, in the current finding, in addition to the effects of diet, genotype effects also significant ($P < 0.05$) different on total non-carcass fat contents. Even though, supplemented Awassi and Washera crossbred lambs had comparable total non-carcass fat composition, Washera F_1 crossbred lambs showed comparatively higher fat contents than Awassi F_1 crossbreds in relation to their body weight difference.

4.5 Genotype and supplemented feed effects on edible and non-edible, non-carcass part

Accordingly, intellectual prohibited cultural and religious taboo of local communities, edible components of non-carcass organs, which presented as liver, tongue, heart, kidney, empty gastrointestinal content and tail fat are the most common and presented in **Table 6**. Hence, liver and heart weight comparable value between Wollo highland and Washera crossbred lambs; however, Awassi crossbred lambs had significantly ($p < 0.05$) higher than the other. The reason behind this might be larger body size and physiological appearance of the genotype. However, non-significant variation between supplemented and non-supplemented groups of all genotypes were recorded, while the kidney and intestine weight had a comparable amount for all genotypes and feeding type. Roughage part of animal feed obvious to feel rumen content and the the green forge grazing was equally accessible to all genotypes and which was the reason for comparable intestinal weight. Whereas the tail size had comparable value for Awassi crossbred and Wollo highland breed ram lambs, Washera crossbred lambs had a significantly ($P < 0.05$) larger tail size than other two genotypes. This also indicated that Washera F_1 crossbred ram-lambs shown larger fat development nature and that might be because of largest tail weight.

In agreement with current finding, Riley et al. [39] and Teklu [40] were reported the majority of edible offal components was not affected ($P > 0.05$) by the supplemented feed. As a remarkable feature of Awassi crossbred lambs more advanced with liver, tongue and heart weight. This perceptible difference resulted from large body size and genotype effect. In concurrence with the current result, Riley et al. [39] indicated that differences in internal organs were more influenced by age, breed and sex of the animals rather than plane of nutrition, whereas kidney and empty gastrointestinal track weight cover the larger portions of edible non-carcass components compared with all genotypes, which aligned with Teklu [40]. This implies animals consume more feed, their stomach enlarged to accommodate the larger ingesta and thicker to resist the workload on it and this may increase the volume and weight of the gastrointestinal tract as a whole.

Except lung with trachea and spleen, all non-edible offal components were not affected by supplemented diet and indicating that variation of supplementation diet not influenced the non-edible non-carcass components. The non-edible non-carcass contents of head, digestive content and blood volume significant difference ($p < 0.05$) among genotypes and this might be slaughtered body weight differences and the inherent genotype effect. In agreement with the current study, Prasad and Kirton [41] reported live weight status of the animals could affect the production efficiency of carcass offal and considered as depressing factor for hot and cold carcass weight extent and their dressing percentage. However, the nutritional effect not significantly visible for most non-edible non-carcass component weight and which in agreement with Teklu [40] but disagree with Michael and Yaynshet [42]. In general the larger extent of non-carcass non-edible components could be reduced the edible carcass and non-carcass amount, hence, through breed selection task, need to be considered the non-carcass non-edible content of genotype.

5. Conclusion and recommendation

The study conducted at feedlot productive performance evaluation of Wollo highland sheep breed and their F_1 crossbreeds of Awassi and Washera sheep in Ethiopia. The objectives of the research is grazing and feedlot based productive performance evaluation of Wollo highland sheep breed and their F_1 crosses.

The average daily weight gain (ADG), total body weight change and final body weights of supplemented group Awassi F_1 crossbred and Wollo highland ram lambs significantly higher than non-supplemented groups. Awassi F_1 crossbred lambs growth performance significantly higher than Wollo highland and Washera F_1 crossbred lambs and followed by supplemented Wollo highland breed lambs. Wollo highland breed had ability to increase their body weight compared with other selected indigenous breed types of the country and have potential value for fattening purpose and productive potential genetic improvement practice, as far as their nutritional requirement is maintained.

The effect of genotypes on average daily weight gain of Awassi crossbred ram lambs had the largest value of breed selection in the current study. Therefore, the effect of both genotype and supplementation diet have an advanced value for lamb body weight gain improvement practices. Moreover, cost effective concentrate feed supplementation on natural pasture controlled grazing have to give appropriate attention by smallholder sheep producers and fatteners.

Carcass composition used as a tool to characterize breeds for possible identification of potential genetic resource of lean meat type of lamb production and identify management alternatives to suit different breeds. Differences in carcass merits between genotypes are likely to govern the choice and development of breeds for specific production objective. Natural pasture controlled grazing management important alternative for productive and organic product improvement practices.

Supplementation diet does not have significant effect on hot carcass weight dressing percentage however, further research is important to confirm at different level of supplementation feeding trial. Cold carcass weight dressing percentage (CCWDP) has a significant difference between supplemented and non-supplemented groups of each of the three genotype in the present study and its important parameter for carcass productivity improvement practice.

Awassi F_1 crossbred progenies designated for promising attributes for higher body weight gain and carcass yield characteristics productive trait and good fertility rate; however, further research verification activities suggested with different blood level of crossbred progenies performance evaluation. The genotype and supplementation diet effect has profound factors to enhance productive and farmers' production objectives decision. Hence, researchers need to investigate farmers' interest and potential of available breed type through genetic and phenotype performance study. Effective concentrate feed supplementation on controlled natural pasture grazing had significant impact on ram lambs productive performance improvement and it is crucial to create appropriate understanding for fatteners, traders and other sheep producers.

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Conflict of interest

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Abbreviations

CSA	Central Statistics Authority
EPA	extension planning area
SPS	sanitary and phytosanitary standards
UNCTD	United Nations Conference on Trade and Development

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